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## ORIGINAL ARTICLE

# Timing of Spermatarche and Menarche are Associated with Physical Activity and Sedentary Behavior Among Korean Adolescents

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### Abstract

**Objectives:** This study examined the timing of menarche and spermatarche and their associations with physical activity (PA) and sedentary behavior (SB) after controlling for body mass index (BMI).

**Methods:** Multiple logistic regression analyses were conducted to determine whether the timing of menarche in girls and spermatarche in boys is associated with PA and SB independent of BMI in a nationally representative sample of Korean adolescents (13–18 years;  $N = 74,186$ ).

**Results:** After controlling for age, family economic status, and BMI, early timing of spermatarche among boys was associated with a higher likelihood of engaging in PA and a lower likelihood of engaging in SB for  $< 2$  hours during weekdays. By contrast, boys with late timing of spermatarche were less likely to engage in PA and more likely to engage in SB for  $< 2$  hours. Among girls, early or late timing of menarche was associated with a higher likelihood of engaging in PA and a lower likelihood of engaging in SB.

**Conclusion:** Timing of menarche in girls and spermatarche in boys could be a marker for PA and SB among Korean adolescents. To promote PA and discourage SB among Korean adolescents, school-based, grade-specific interventions can be tailored by the absence or presence of menarche/spermatarche.

## 1. Introduction

Puberty is a complex transition that involves dramatic changes in several domains of human development including biological, physical, psychological, and social development [1]. Although puberty is a universal

phase of adolescents, timing of puberty varies by genetic (e.g., sex, race, parental influence), environmental (e.g., body fatness, nutrition), and socioeconomic/cultural factors (e.g., immigration status) [2]. For example, girls generally experience puberty 18–24 months earlier than boys, and overweight/obese status in early childhood is

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associated with advanced pubertal maturation [2,3]. The individual variations in puberty can be viewed by three aspects, namely, timing, status, and tempo [4,5]. Timing refers to relative or expected pubertal maturation at a given chronological age or within specific reference groups such as school class, whereas status refers to the level of development reached by an individual in terms of physical changes at a given time. Tempo of puberty describes how quickly or slowly individuals progress toward full sexual maturity. Among these concepts, the majority of literature that examined the relationship between puberty and physical and/or psychological development used pubertal timing as an indicator of biological maturation [5].

Individual variations in the timing of puberty may influence the adoption of unhealthy behaviors. Specifically, a comparison between those who mature on time and those who mature late shows that adolescents who mature early are at a higher risk of exposure to several psychological, social, and health disadvantages [6]. For example, girls who experience puberty earlier than their counterparts are more susceptible to adverse health behaviors such as earlier alcohol use [7], cigarette smoking [8], and eating disorder [9]. Furthermore, evidence suggests that early timing of puberty among girls is also associated with decline in physical activity (PA) [10–13], and an increased time spent in sedentary behavior (SB) [14]. Although supporting evidence for boys is lacking, Cumming and his colleagues [15] proposed a biocultural model of maturity, which suggests that antecedent biological variables (e.g., sexual maturation, pubertal timing, changes in body composition) influence different contexts of PA (e.g., energy expenditure, health-related fitness, skill proficiency, sport participation, and performance) directly and indirectly via psychosocial variables (e.g., physical self-concept, body image dissatisfaction, self-esteem).

One of the potential mechanisms explaining the association between high endogenous sex hormone (i.e., estrogen/testosterone) and early puberty is overnutrition in early childhood [2,16]. It is particularly well-documented among girls that increased adiposity may trigger estrogen production and lead to the early onset of menarche [2,3]. Only a few studies have examined the relationship between puberty and body mass index (BMI) among boys by using different measures [e.g., voice break, age at onset of pubertal growth spurt, peak height velocity, pubic hair growth, testicular volume, and/or penis length], and the results reported have been inconsistent [17–21]. However, a recent study examining the trend of age at spermatarche and its association with BMI among Chinese school boys found that a higher BMI or BMI-for-Age *z*-score was associated with an increased likelihood of having reached spermatarche, indicating the overlapping trend of earlier age at spermatarche with increase in BMI over the past 15 years among Chinese boys [3].

While much of the research is conducted in the European and North American contexts, studies among Korean adolescents are limited. In Korea, health-care costs associated with precocious puberty (i.e., the onset of signs of puberty before the age of 7–8 years in girls and 9 years in boys) have increased remarkably since the past decade. The total cost of health care for precocious puberty was approximately US \$2.3 million in 2006 and US \$17.9 million in 2010 [22]. This trend overlaps with the increasing trend of childhood obesity in Korea, the prevalence of which doubled from 5.4% in 1998 to 10.8% in 2008 [23,24]. Greater understanding of the associations between pubertal timing, PA, and SB, independent of weight status among Korean adolescents may help researchers and policy makers to develop health-promotion strategies for adolescents during these formative years (i.e., adolescence). Therefore, the purpose of this study was to examine the associations between pubertal timing, PA, and SB after controlling for BMI. It is hypothesized that adolescents who experience menarche and spermatarche earlier or later than their peers will show negative outcomes.

## 2. Materials and methods

### 2.1. Data/sample

Data collected from the eighth Korea Youth Risk Behavior Web-based Survey (KYRBS) in 2012 were used for the analysis. KYRBS is an annual, cross-sectional, nationwide school-based web survey that monitors health risk behavior among Korean adolescents in Grades 7–12; respondents were recruited using a stratified multistage probability sampling design [25]. Before survey administration, consent was obtained from the participating school boards, individual schools, and teachers. In June 2012, students completed a self-administered, 129-item questionnaire in a computer laboratory under the supervision of teachers assigned by principals in each school during regular school hours. Before beginning the online survey, students were asked to read the research information letter, which indicated that the participation in this survey is anonymous and voluntary. The survey is designed to take approximately 40–45 minutes to complete. All surveys included a set of questions that were supplemented with additional focus questions to gain further information on specific issues. The core information collected includes demographic background (e.g., age, sex), health behaviors (e.g., smoking, alcohol use, PA), and health outcomes (e.g., self-reported health, obesity). A total of 76,980 students from 400 middle and 400 high schools participated (response rate: 96.4%). In this study, 74,186 students (48.5% of girls) who completed the survey were included in the analysis after excluding those with missing scores in height and weight, and those aged < 12 years or aged > 19 years ( $n = 2,794$ ). Weights were

assigned to each respondent to give an equal probability of being sampled from the entire Korean population aged between 12 years and 19 years. The survey protocol was approved by Korea Centers for Diseases Control and Prevention (approval number: 11758) [25].

## 2.2. Measures

### 2.2.1. Pubertal timing

Individual menarcheal and spermarcheal data were collected by the status quo method. The question was “When did you experience your first menstruation (i.e., menarche)/ejaculation (i.e., spermarche)?” Response options were ranged from 1 (have not yet experienced) to 14 (Grade 12). For data analysis, the average of pubertal timing was calculated except for those who have not yet experienced menarche/spermarche; the average grade of puberty was Grade 7 ( $8.13 \pm 1.76$ ) for boys and Grade 6 ( $7.27 \pm 1.27$ ) for girls. Students were then categorized into four pubertal timing groups by sex: Group 1 (menarche in Grades 1–5 for girls; spermarche in Grades 1–6 for boys), Group 2 (average: menarche in Grade 6 for girls; spermarche in Grade 7 for boys), Group 3 (menarche in Grades 7–8 for girls; spermarche in Grades 8–9 for boys), and Group 4 (have not yet experienced and maturation in or over Grade 9 for girls; have not yet experienced and maturation in or over Grade 10 for boys). Menarche is a distinctive and commonly used measure of pubertal timing among girls [3]. First ejaculation, also known as spermarche, has been used to indicate pubertal timing in previous studies [3,26]. The average grades of menarche and spermarche were similar to those reported previously [1,26].

### 2.2.2. Body mass index

BMI ( $\text{kg}/\text{m}^2$ ) was calculated by self-reported height and weight. Each BMI score was then categorized into nonoverweight (BMI percentile 0–84.9<sup>th</sup>) and overweight (BMI percentile  $\geq 85.0^{\text{th}}$ ) based on the age- and sex-specific BMI reference data for Korean children and adolescents [27].

### 2.2.3. Physical activity/sedentary behavior

Moderate-to-vigorous PA (MVPA) and SB were measured using questions adopted from the International Physical Activity Questionnaire [28]. MVPA was measured by asking participants the following questions: “For the past seven days: (1) How many days did you engage in activities resulting in an increase of heart rate or experiencing shortness of breath (moderate-to-vigorous) for more than 60 minutes?; (2) How many days did you engage in weight-bearing exercise?” Questions were scaled from 1 (no participation at all) to 8 (7 d/wk). PA was categorized into four groups (i.e., none, 1–2 times, 3–4 times,  $> 5$  times). To measure SB, the following questions were asked. “How many hours a day: (1) did you spend your leisure time watching television, playing video game, Internet

browsing, or chatting with friends during the last 5 weekdays (2) and on weekends?” Response options were ranged from 1 ( $< 1$  h/d) to 6 ( $> 4$  h/d).

### 2.2.4. Covariates

Family socioeconomic status and chronological age were included as covariates. Family socioeconomic status was measured by asking participants to rate their economic status from 1 (low) to 4 (high).

## 2.3. Statistical analysis

All analyses were performed for boys and girls separately. The population weight provided by KYRBS was applied to estimate a representation of the target population. Descriptive statistics were calculated and expressed as means and standard deviations or as percentages. To examine the associations between relative pubertal timing, BMI, and PA/SB, a series of logistic regression models stratified by sex were conducted. All analyses were controlled for age and family socioeconomic status. Models examining the associations between pubertal timing and health behavior were further adjusted for BMI. Analyses were conducted using IBM SPSS 20.0 (Armonk, NY: IBM Corp.) and the results were reported as predicted odds ratio (OR) and 95% confidence interval (95% CIs). The alpha level was set at 0.05.

## 3. Results

The sample characteristics of the study population by sex are presented in Table 1. Of the 74,186 respondents, average age of all respondents was 14.94 years (standard deviation = 1.75). Relative pubertal timing among respondents was described; 15.4% of boys and 23.8% of girls experienced puberty earlier than their peers. Boys were more physically active than girls. The proportion of students engaging in MVPA  $> 5$  times/wk was 17.3% among boys and 6.1% among girls. More girls engaged in SB  $\geq 4$  h/d than boys during weekdays (16% vs. 11.9%) and on weekends (30.4% vs. 24.8%).

Table 2 shows the associations between relative pubertal timing, PA, and SB among Korean adolescent boys after controlling for age, family economic status, and BMI. Compared to boys with average pubertal timing (referent group), those with early pubertal timing were more likely to engage in MVPA for 60 minutes for  $> 5$  times/wk (OR = 1.04, 95% CI = 1.02–1.05) and muscular strengthening exercises (OR = 1.06, 95% CI = 1.05–1.07). In contrast, boys with late pubertal timing were less likely to engage in MVPA (OR = 0.99, 95% CI = 0.97–1.00 for Group 3; OR = 0.95, 95% CI = 0.94–0.96 for Group 4) and muscular strengthening exercise (OR = 0.91, 95% CI = 0.90–0.92 for Group 3; OR = 0.85, 95% CI = 0.84–0.86). During weekdays, boys with early pubertal timing were less

**Table 1.** Sociodemographic characteristics of the sample ( $N = 74,186$ )—2012 Korea Youth Risk Behavior Web-based Survey.

	Total ( $N = 74,186$ )	Boys ( $n = 38,221$ )	Girls ( $n = 35,965$ )
Age (y), mean $\pm$ SD	14.94 (1.75)	14.96 (1.75)	14.92 (1.74)
BMI ( $\text{kg}/\text{m}^2$ ), mean $\pm$ SD*	20.60 (3.02)	20.90 (3.28)	20.26 (7.93)
Nonoverweight (0–85%)	89.0	85.4	92.6
Overweight ( $\geq 85\%$ )	11.0	14.6	7.4
Family economic status (%)			
Low	30.7	33.4	27.7
Middle	46.7	44.6	49.0
High	22.6	22.0	23.3
Pubertal timing (%) <sup>†</sup>			
1	19.4	15.4	23.8
2 (average)	23.3	14.8	32.6
3	25.7	18.1	34.1
4	31.6	51.7	9.5
Physical activity (%)			
Moderate-to-vigorous physical activity $\geq 60$ min/d			
None	36.9	27.9	46.8
1–2 times/wk	32.6	31.7	33.5
3–4 times/wk	18.5	23.1	13.5
$\geq 5$ times/wk	12.0	17.3	6.1
Muscular strengthening exercises			
None	51.7	37.1	67.8
1–2 times/wk	29.1	34.7	23.0
3–4 times/wk	11.4	16.3	6.0
$\geq 5$ times/wk	7.8	11.9	3.2
Sedentary behavior (%)			
Weekdays			
> 2 h	52.1	54.6	49.3
2–3 h	23.0	23.3	22.7
3–4 h	11.0	10.2	12.0
$\geq 4$ h	13.9	11.9	16.0
Weekends			
> 2 h	29.9	32.3	27.2
2–3 h	24.7	25.8	23.5
3–4 h	18.0	17.1	18.9
$\geq 4$ h	27.5	24.8	30.4

\*Body mass index: calculated based on the 2007 BMI-for-Age in Korean children and adolescents [27]; <sup>†</sup>Pubertal timing: 1 (menarche in Grades 1–5; spermatarche in Grades 1–6); 2 (average: menarche in Grade 6; spermatarche in Grade 7); 3 (menarche in Grades 7–8; spermatarche in Grades 8–9); and 4 (menarche in or over Grade 9 or have not experienced yet; spermatarche in or over Grade 10 or have not experienced yet). BMI = body mass index; SD = standard deviation.

likely to engage in SB for  $< 2$  h/d (OR = 0.94, 95% CI = 0.93–0.95), whereas those with late pubertal timing reported the opposite (OR = 1.10, 95% CI 1.09–1.11 for late timing; OR = 1.01, 95% CI = 1.00–1.02 for delayed timing) compared with the referent group. On weekends, boys with either early (OR = 1.02, 95% CI = 1.01–1.04) or late timing of puberty (Group 4: OR = 1.06, 95% CI = 1.05–1.07) were more likely to have SB for  $< 2$  hours compared with the referent group.

The associations between relative pubertal timing, PA, and SB, independent of BMI among Korean girls are shown in Table 3. Among girls, early, late, and delayed timing of puberty, compared to girls with average pubertal timing, were associated with higher

odds of reporting the participation in MVPA for  $> 60$  minutes and 5 d/wk (OR = 1.05, 95% CI = 1.04–1.07 for early timing; OR = 1.07, 95% CI = 1.06–1.09 for late timing; OR = 1.29, 95% CI = 1.26–1.32 for delayed timing), muscular strengthening exercises for  $> 3$  d/wk (OR = 1.13, 95% CI = 1.11–1.15 for early timing; OR = 1.12, 95% CI = 1.11–1.14 for late timing group 3; OR = 1.26, 95% CI = 1.24–1.28 for late timing group 4), and SB for  $< 2$  h/d during weekdays (OR = 1.04, 95% CI = 1.03–1.05 for late timing; OR = 1.28, 95% CI = 1.16–1.29 for delayed timing) and on weekends (OR = 1.04, 95% CI = 1.03–1.05 for early timing; OR = 1.01, 95% CI = 1.00–1.02 for late timing group 3; OR = 1.34, 95% CI = 1.32–1.36 for late timing group 4).

**Table 2.** Associations (OR and 95% CI) between relative pubertal timing, physical activity, and sedentary behavior after controlling for BMI\* among Korean adolescent boys ( $N = 38,221$ )—2012 Korea Youth Risk Behavior Web-based Survey.

		1 <sup>†</sup>	2 (average) <sup>†</sup>	3 <sup>†</sup>	4 <sup>†</sup>
		OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Moderate-to-vigorous physical activity $\leq 60$ min/d	$\geq 5$ times/wk	1.04 (1.02–1.05)	1	0.99 (0.97–1.00)	0.95 (0.94–0.96)
Muscular strengthening exercise	$\geq 3$ times/wk	1.06 (1.05–1.07)	1	0.91 (0.90–0.92)	0.85 (0.84–0.86)
Sedentary behavior (weekdays)	$< 2$ h/d	0.94 (0.93–0.95)	1	1.10 (1.09–1.11)	1.01 (1.00–1.02)
Sedentary behavior (weekends)	$< 2$ h/d	1.02 (1.01–1.04)	1	0.99 (0.98–1.00)	1.06 (1.05–1.07)

\*Body Mass Index (BMI): calculated based on the 2007 BMI-for-Age in Korean children and adolescents [27]; <sup>†</sup>Pubertal timing: 1 (spermarche in Grades 1–6), 2 (average: spermarche in Grade 7), 3 (spermarche in Grades 8–9), and 4 (spermarche in or over Grade 10 or have not experienced yet). All analyses are adjusted for chronological age, family economic status, and BMI.  $p < 0.05$ . CI = confidence interval; OR = odds ratio.

## 4. Discussion

This study examined the associations between pubertal timing, PA, and SB, independent of BMI among Korean adolescents. This study offers a better understanding of the relationship between pubertal timing and health behavior among adolescents. Consistent with the previous findings, our results suggest that pubertal timing is a potentially relevant marker associated with PA and SB, independent of BMI, in a representative sample of Korean adolescents. A previous study indicated that pubertal timing predicts psychological outcomes among girls but not among boys [5]. The results of our study add to the current literature that pubertal timing is also an important predictor for behavioral outcomes among both boys and girls.

Specifically, early timing of puberty among boys was associated with a higher likelihood of engaging in PA, whereas a decreased likelihood of engaging in PA was found among boys with late pubertal timing. By contrast, early timing of puberty was associated with a higher likelihood of spending time in SB for  $> 2$  hours during weekdays, whereas boys with late timing of puberty showed the opposite (i.e., less likely to spend  $> 2$  hours in SB). Although boys with early pubertal timing are more

likely to engage in MVPA and strengthening exercises, they were more likely to spend  $> 2$  h/d in SB during weekdays (i.e., high PA and high sedentary). By contrast, boys with late pubertal timing were less likely to engage in PA, but more likely to engage in SB for  $< 2$  hours (i.e., low PA and low sedentary). Given that PA and SB are likely to have combined effects on health among young people [29], Korean adolescent boys who experience puberty early or late may be predisposed to negative health conditions. Regardless of individual variations in weight status, promoting PA among boys with late timing of puberty and discouraging SB among boys with early timing of puberty may positively contribute to their health.

Early or late timing of puberty among girls was associated with physically active lifestyle (i.e., high PA and low SB) relative to their peers with average timing of puberty after controlling for weight status. This is somewhat inconsistent with previous findings. For example, previous studies examining the relationship between pubertal timing and PA after controlling for age and BMI reported nonsignificant associations [30,31]. By contrast, in a longitudinal examination by Davison and colleagues [12], advanced maturation at 11 years of age was associated with low levels of MVPA at 13 years of age among 178 American girls after controlling for

**Table 3.** Associations (OR and 95% CI) between relative pubertal timing, physical activity, and sedentary behavior after controlling for BMI\* among Korean adolescent girls ( $N = 35,965$ )—2012 Korea Youth Risk Behavior Web-based Survey.

		1 <sup>†</sup>	2 (average) <sup>†</sup>	3 <sup>†</sup>	4 <sup>†</sup>
		OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Moderate-to-vigorous physical activity $\leq 60$ min/d	$\geq 5$ times/wk	1.05 (1.04–1.07)	1	1.07 (1.06–1.09)	1.29 (1.26–1.32)
Muscular strengthening exercise	$\geq 3$ times/wk	1.13 (1.11–1.15)	1	1.12 (1.11–1.14)	1.26 (1.24–1.28)
Sedentary behavior (weekdays)	$< 2$ h/d	1.00 (0.99–1.01)	1	1.04 (1.03–1.05)	1.28 (1.16–1.29)
Sedentary behavior (weekends)	$< 2$ h/d	1.04 (1.03–1.05)	1	1.01 (1.00–1.02)	1.34 (1.32–1.36)

\*Body mass index (BMI): calculated based on the 2007 BMI-for-Age in Korean children and adolescents [27]; <sup>†</sup>Pubertal timing: 1 (spermarche in Grades 1–6), 2 (average: spermarche in Grade 7), 3 (spermarche in Grades 8–9), and 4 (spermarche in or over Grade 10 or have not experienced yet). All analyses are adjusted for chronological age, family economic status, and BMI.  $p < 0.05$ . CI = confidence interval; OR = odds ratio.



covariates including body fat, and this relationship between maturation and PA was mediated by global self-worth, depression, and maturity fears. It is likely that the differences in findings across studies are due to different measures used to measure pubertal timing and/or health behavior (i.e., PA and SB). Nonetheless, perhaps there are mechanisms explaining the relationship between average timing of puberty and unhealthy behaviors (i.e., low PA and high SB) relative to their off-time peers among Korean girls. A recent review examining the correlates of PA among Korean girls indicated that traditional gender roles and gender inequality in physical education class may prevent girls from being physically active [32]. Indeed, boys who engage in MVPA for > 5 times/wk were almost three-fold of girls in our study (17.3% vs. 6.1%). Girls with average pubertal timing may have more friends who are not physically active compared to girls with early or late timing of puberty.

Our study has several limitations to be acknowledged. We used a self-administered questionnaire, which has been noted as a weakness in comparison to direct or objective measures; however, the large sample size provides representative estimates of Korean adolescents. Future studies may benefit from incorporating the objective measure of PA and SB such as accelerometer. The study also relied on a single-item, self-report to assess pubertal timing. Grade at menarche/spermarche refers to either the past or to an event that one has not experienced yet. Using other measures of pubertal timing (e.g., subjective pubertal timing, secondary sex characteristics) or other dimensions of puberty [e.g., pubertal status using age at peak height velocity, tanner stage, Pubertal Development Scale (PDS)] may provide more insight on this topic than direct inquiry about the onset of one event. In addition, although chronological age can be a better measure than school grade for pubertal timing, KYRBS does not provide full information in age (i.e., year, month, and date or birth), and therefore, it was impossible to provide age-specific data. However, school grade can be a better predictor of PA and SB in the Korean context given the Asian age reckoning and school system. Specifically, newborns start at the age of 1 year, and commonly go to elementary school at the age of 8 years in Asian age reckoning. As a result, Korean students spend most of their time with their peers in the same grade, rather than with peers in the same chronological age *per se*. Furthermore, previous studies have reported that girls and boys may respond differently to the onset of menarche and spermarche based on how prepared they are for the event [33,34]. For instance, boys tend to report that they have experienced spermarche when they have not because it reflects muscularity. Nonetheless, the only available datum regarding pubertal timing was menarche for girls and spermarche for boys in the self-reported data from the KYRBS. In addition, although

the average timing of menarche/spermarche among our sample was similar to those reported in previous studies [1,3], misclassification error might have occurred when categorizing pubertal timing into four groups. To decrease the validity of these threats in future work, it is recommended that KYRBS should adopt more robust, yet noninvasive measures of pubertal maturation (e.g., secondary sexual characteristics, PDS, or both).

Despite such limitations, we found that pubertal timing was a potential relevant marker associated with PA and SB, independent of BMI among Korean adolescents. Our results have implications for public health policy. Furthermore, interventions promoting active living among adolescents should be tailored based on different maturational timing with other sociodemographic characteristics; premenarcheal/spermarcheal stage may be a critical period for health behavior formation. Furthermore, physicians and health professionals are suggested to use early or late timing of puberty as a marker for overweight and physically inactive lifestyle among Korean adolescent boys. It is recommended to promote adopting physically active lifestyle among boys with early or late timing of puberty. Specifically, discouraging overall SB should be focused on boys with early pubertal timing and promoting PA should target boys with late pubertal timing. In addition, it may help researchers to better understand how relative pubertal timing influences health behavior by incorporating mediating or moderating variables (i.e., psychosocial factors associated with puberty) in future studies. Longitudinal tracking is also required for future studies. It is still unclear whether pubertal timing influences the decline in PA and increase in SB.

Early or late timing of puberty could be a relevant marker for physically inactive lifestyle among Korean adolescent boys. The results of our study has some consistent and inconsistent findings compared with existing literature mostly from Western countries; nonetheless, the present study makes a unique contribution to the limited existing research examining pubertal timing and health behavior, particularly among adolescent boys. School-based interventions to promote PA and discourage SB among Korean adolescents should take individual differences in pubertal timing into consideration.

## Conflicts of interest

All authors have no conflicts of interest to declare.

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